Case History	Self-Excited Vibration Induced by Tilting Pad Journal Bearing	Rotating machinery
Self-excited Vibration		

Object Machine

Rotor & tilting pad bearing system mounted on balancing equipment (refer to Fig.1)

Observed Phenomena

During acceleration up to the rated rotational speed of 18,800 rpm, self-excited vibration occurred at 13,000 rpm.

Cause Presumed

During acceleration of the rotor & tilting pad bearing system, vibration of 88.5 Hz (5,300 cpm) occurred suddenly at than the rotational speed 13,300 rpm (220 Hz), being rapidly followed by a large vibration with a half amplitude in excess of 120 μm. As shown in Fig.3, the whirl locus was a nearly circular asynchronous whirling vibration in the forward direction. Although it is generally believed that tilting pad bearings do not easily cause self-excited vibrations such as oil whip and oil whirl, an estimation was made that this was an unstable phenomenon due to bearings, as no other causes were identified.

Analysis and Data Processing

The bearings used were existing ones on the balancing equipment, and not the bearings planned for this rotor. High speed balancing was performed without a previously prepared plan, and these bearings were used on a temporary basis. Specifications of the bearing and journal are enumerated in Table 1. A standard combination normally uses a bearing clearance ratio of 1.4 to 2.2% with a tolerance, a preload factor m = 0.0, and turbine oil VG32, which has experienced no self-excited vibration due to bearings. In this example, however, the journal diameter was about 0.3 mm smaller compared to the standard combination journal diameter (φ 100), so that the clearance ratio was set a little wider (4.4 to 5.3%).

Fig.5 shows three dimensional representations of the measured rotor vibration displacement and bearing pedestal velocity. Upon reaching 13,300 rpm, a vibration of the asynchronous component (88.5 Hz) suddenly grew up.
It was estimated that in this combination, its preload factor of 0 (zero) and too large bearing clearance led to weak pad restraint by hydraulic force and instability of the pad itself, thus developing self-excited vibrations.

Countermeasures and Results

With a view to enhancing the bearing preload factor and to narrowing the bearing clearance, 0.1 mm thick stainless steel shims were inserted on the backside of the pad as illustrated in Fig.4. Since these pads are of a symmetrical center pivot type, it is sufficient to only to insert the shims in the width direction at the pad center. Still, in order to prevent slippage during usage, the shims was fabricated a hole for a fastening pin.

After implementing the countermeasures, the preload factor was m = 0.388 to 0.455, and the bearing clearance ratio was 2.4 to 3.3% (refer to Table 1).
Figure 6 provides the measured results of shaft vibration displacement and the bearing pedestal velocity after taking the countermeasures. The excessively large self-excited vibration disappeared, allowing acceleration up to the rated rotational speed. Since a newly generated vibration of 39.7 Hz has small amplitude and is stable, no cause investigation has been conducted and no countermeasure has been taken.

Lesson Learned

Even tilting pad bearings may easily cause self-excited vibration.

References

For example, Taura, H., Tanaka, M., Suzuki K.:. *Study on the Stability of Tilting Pad Journal Bearings* (*Report No.2 on experiment results*), JSME, No.01-5, Proceedings of Dynamic & Design Conference (2001) p.109 (in Japanese)

Keyword

Tilting pad journal bearing, oil film bearing, self-excited vibration, oil whip, oil whirl

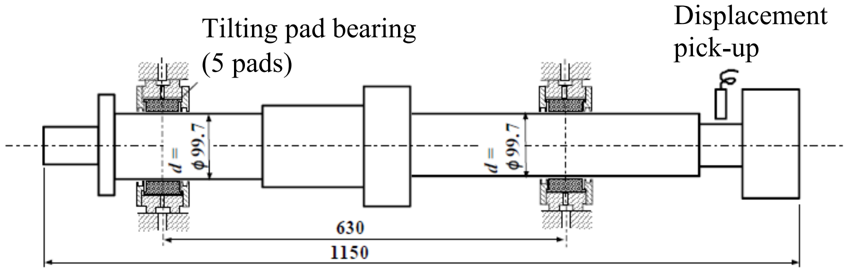


Fig.1 General arrangement of rotor & bearing (bearing load: 26/57 kgf)

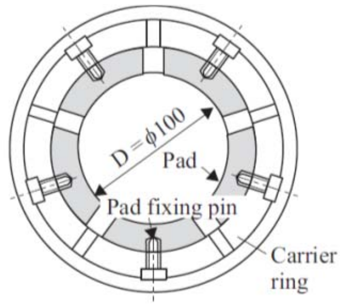


Fig.2 Tilting pad bearing
(5 pads, m = 0.0, L/D = 0.5)

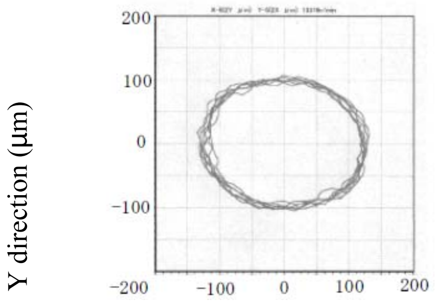


Fig.3 Locus of whirl of rotor vibration

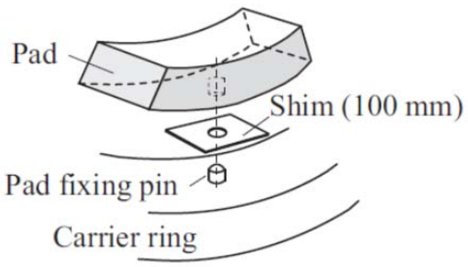
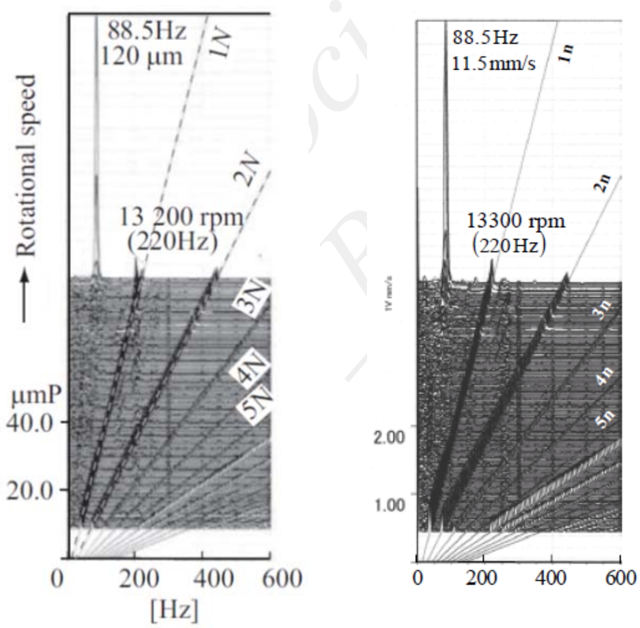


Fig.4 General arrangement of countermeasure

Table 1 Specifications of the bearing and journal

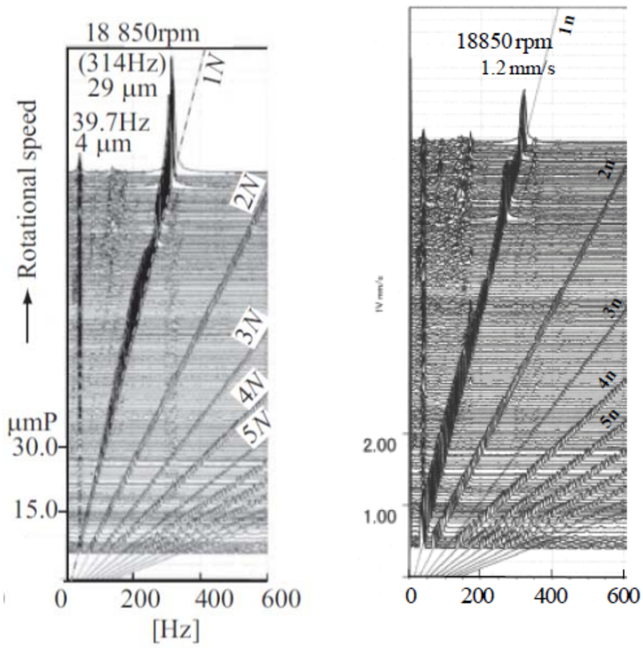
Unit: mm

Standard combination	Drawing dimensions	Tolerance (bottom limit)	Tolerance (top limit)
Bearing inner diameter *D*	100.0	0.140	0.195
Standard journal diameter	100.0	-0.022	0.0
Bearing radial clearance (when in concentricity: *Cp*)		0.070	0.109
Bearing radial clearance (when assembled: *Cb*)		0.070	0.109
Preload factor (m = 1-Cb/Cp)		0.0	
2Cb/D: clearance/journal radius		0.0014	0.0022
Occurrence of vibration			
Journal diameter used d	99.7	-0.030	0.0
Bearing radial clearance (Cp = Cb)		0.220	0.263
2Cb/D: clearance/journal radius		0.0044	0.0053
Countermeasure (0.1 mm shim added on the pad back side)			
Clearance after adding shim Cb		0.120	0.163
Preload factor (m = 1-Cb/Cp)		0.455	0.381
2Cb/D: clearance/journal radius		0.0024	0.0033



(a) Rotor vibration amplitude (b) Pedestal velocity

Fig.5 Self-excited vibration occurred at 13,300 rpm



(a) Rotor vibration amplitude (b) Pedestal velocity

Fig.6 Vibration condition after taking countermeasures